LISA

Laser Interferometer Space Antenna

LISA Project Status

Presented to the:
Structure and Evolution of the Universe Subcommittee (SEUS)

Maryland Inn and Conference Center

February 24, 2004

Bryant Cramer
LISA Project Manager

Beyond Einstein: From the Big Bang to Black Holes

Topics

- Management
- LIST Activities
- Formulation
- Technology Development
- Integrated Modeling
- LISA Pathfinder

LISA Management (1 of 4)

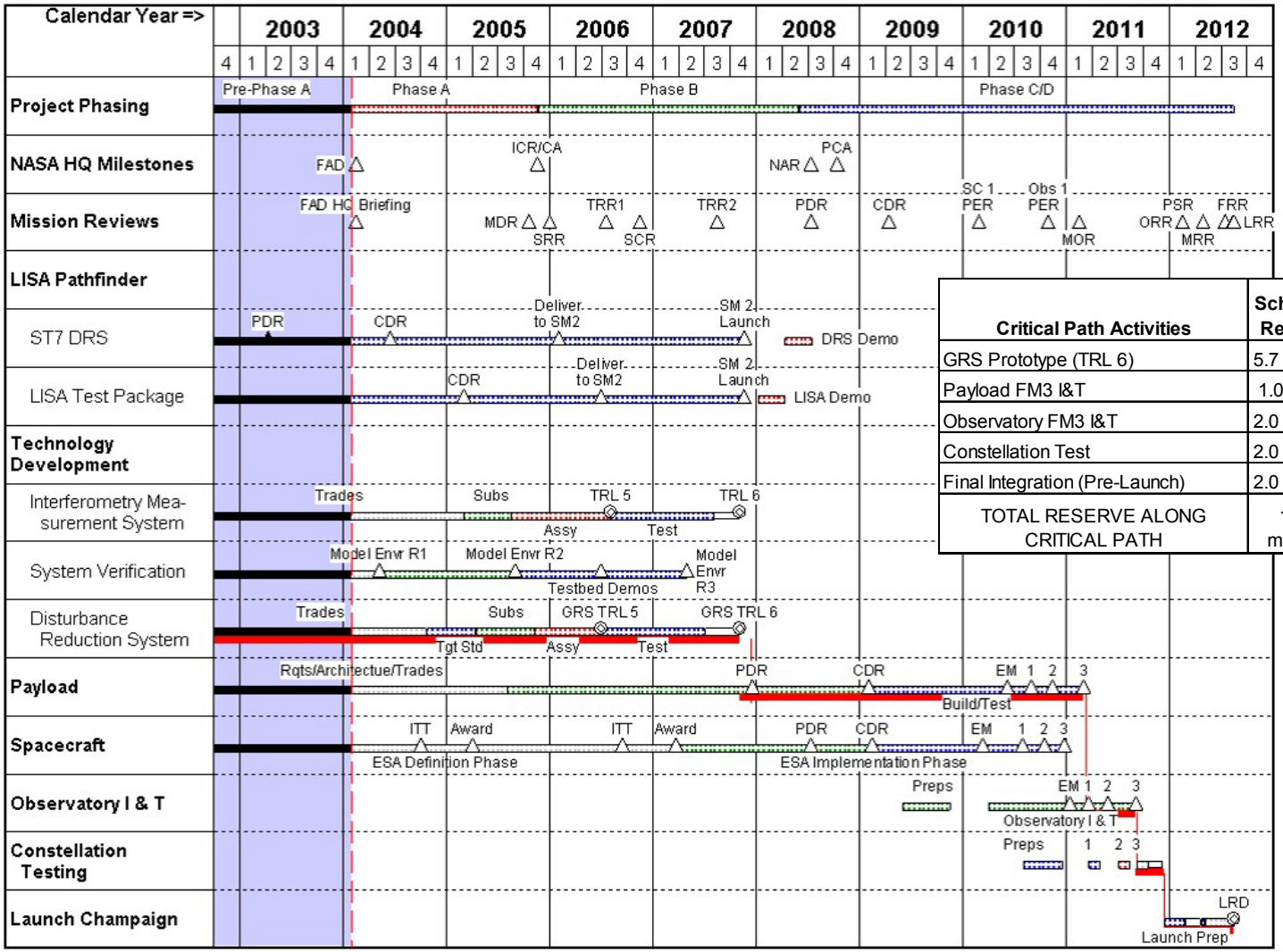
Beyond Einstein: From the Big Bang to Black Holes

- LISA budget for FY-04 and FY-05 is less than anticipated
- Originally planned to begin Formulation (Phase A) in FY-04
- Budgetary reductions will result in the following:
  - Early Project milestones delayed
  - Delayed start in Formulation
  - Replan of the Technology Development effort underway:
    - Some alternatives may be deleted
    - Near-term focus on critical, long-lead work
    - Life testing of the micro-thrusters and lasers should not be further delayed
    - High risk areas go to the top of the list after long-lead work
- Budget guidelines may vary over the next few months
- Current replanning identifies prioritized contingencies to accommodate changing guidelines

LISA Management (2 of 4)

Beyond Einstein: From the Big Bang to Black Holes

Status Date: 01/31/04
Rev 1 Date: 11/30/03



Critical Path Activities	Schedule Reserve
GRS Prototype (TRL 6)	5.7 months
Payload FM3 I&T	1.0 month
Observatory FM3 I&T	2.0 months
Constellation Test	2.0 months
Final Integration (Pre-Launch)	2.0 months
TOTAL RESERVE ALONG CRITICAL PATH	12.7 months

Legend
- = Critical Path
- = Major Milestone
- = TRL
- = Launch

LISA Management (3 of 4)

Beyond Einstein: From the Big Bang to Black Holes

- As with the budget, the schedule is being replanned:
  - Early milestones will slip possibly a year
  - Overall priority for the Replan:
    - Long-lead technologies
    - High risk technologies with no good alternatives
    - System Engineering work to complete requirements definition
    - Other Formulation work
- Remaining synchronized with ESA LISA activities is a primary concern:
  - Must plan around incurring avoidable additional expenses in Europe
  - Developing strategies to “buy back” schedule after FY-05
  - Working hard to hold the Pathfinder schedule
  - Placing greater reliance on early ESA definition studies may work to reduce the overall schedule impact

LISA Management (4 of 4)

Beyond Einstein: From the Big Bang to Black Holes

- NASA and ESA have been unable to agree on who should integrate the payload onto the spacecraft for over a year
- Consequently, ESA proposed to swap payload and spacecraft responsibilities in a NASA / ESA Bilateral Meeting on December 15, 2003
- In this arrangement, ESA would be responsible for the development and integration of the payload while NASA would be responsible for the development and integration of the spacecraft
- NASA would still contribute approximately half of the payload, but would no longer be responsible for the integration of the payload
- OSS has asked the Project to define the advantages and disadvantages of accepting the ESA offer
- OSS has also asked the Project to define the organizational changes necessary to implement the new ESA proposal
- Project input is due to OSS on March 5th

LIST Activities *(1 of 3)*

Beyond Einstein: From the Big Bang to Black Holes

- The LISA International Science Team (LIST) held its winter meeting on Dec 8&9 on the University of Maryland campus
  - The formal meeting was preceeded by meetings of 3 of the standing working groups: Sources and Analysis, Interferometry, and Inertial Sensors
  - Major topics at the meeting included:
    - A report on Extreme Mass Ratio Inspirals which included major new work undertaken by the Sources and Analysis working group
    - A discussion of important recent development in LISA interferometric techniques including arm-locking and Time Delay Interferometry
    - A discussion of possible formal inclusion of low-frequency and high-frequency requirements into the Science Requirements Document
  - Major conclusions of the meeting include
    - The best estimates of Extreme Mass Ratio Inspiral events look very favorable in terms of detection by LISA and a contemplated increase in sensitivity by a factor of 4 at 5-10 mHz is not required. This is a major finding.
    - Proposed extensions of Time Delay Interferometry are sufficient to reduce laser phase noise when motions of the LISA constellation are taken into account. This has recently been verified by a precise simulation of extended TDI algorithms
    - Arm-locking is an attractive option for LISA and should be studied further by the LISA Project
    - A high-frequency requirement was adopted for inclusion in the Science Requirements. Further discussion of low-frequency requirements is required

LIST Activities (2 of 3)

- Working Group 1 of the LIST has worked over the last several months to obtain a much better estimate of the rate of Extreme Mass Ratio Inspirals (EMRI) and the ability of LISA to detect such inspirals
  - Requirements for detection of EMRI events drive some of the important technical requirements for the LISA mission, e.g. laser power and mirror diameter
  - Major issues include:
    - Estimates of rates of events using analytical and monte-carlo calculations
    - Characterization of waveforms of EMRI events
    - Computing power needed to detect EMRI events
  - Conclusion: Baseline sensitivity of LISA sufficient to detect several EMRI events per year, primarily stellar-mass BHs captured by massive BHs
  - Reports and Publications:
    - "LISA Capture Sources: Approximate Waveforms, Signal-to-Noise Ratios, and Parameter Estimation Accuracy", Barack & Cutler, gr-qc/0310125
    - "Estimates of Detection Rates for LISA Capture Sources", LISA WG1 EMRI Task Group: Barack, Creighton, Cutler, Gaier, Larson, Phinney, Thorne, Vallisneri (December, 2003)
- Arm-locking
  - Following presentations at the winter 2002 and summer 2003 LIST meetings, it was concluded that arm-locking was a potentially advantageous technique for LISA and the LIST should advocate work in this area, including activity by Working Group 2
  - The LISA Project is now studying arm-locking within the framework of the Integrated Technical Teams (ITTs)

LIST Activities *(3 of 3)*

- Upcoming activities and events:
  - Next Science Team Meeting: July, 2004 (ESTEC)
  - 5th International Science Symposium: July, 2004 (ESTEC)
  - Update of Science Requirements Document to include recent results on Extreme Mass Ratio Inspirals, High-Frequency Requirements, and Low-Frequency Requirements
  - Support for conferences: COSPAR, Denver APS, …
  - Drafting of Science Management Plan

Formulation (1 of 2)

- ITTs are designed to draw on the expertise of the community, both scientist and engineers, to establish architecture, and requirements definition in specialized areas.
- Integrated Technical Teams report to the System Engineering Office and their charter is defined by the Systems Managers
- Three ITTs were recently established
  - Interferometry Measurement System (IMS)
  - Disturbance Reduction System (DRS)
  - Constellation
- IMS ITT released a draft “Functional Definition and Reference Architecture of the IMS for LISA” which is available on the VSDE website
- DRS ITT is currently working on a draft Function Description and Reference Architecture for the DRS
- Constellation ITT is currently responsible for acquisition strategy definition and constellation drag-free architecture. Current activities include development of the 19 DOF and 57 DOF model and analysis of the acquisition strategy.

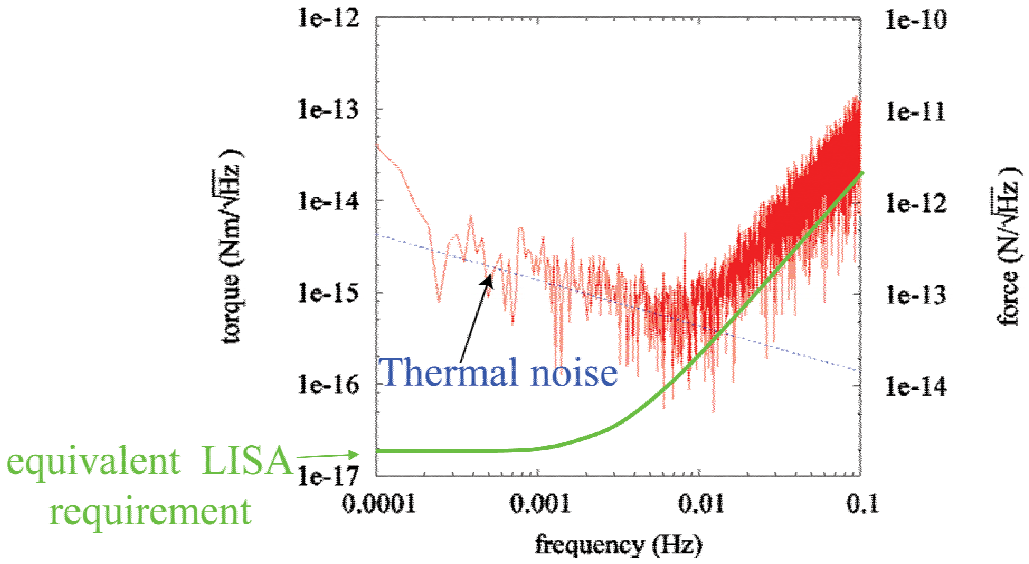
Formulation (2 of 2)

- The Mission Requirements Document (MRD) defines the functions the LISA mission must perform and how well it must perform them in order to fulfil the science requirements
- The Mission Requirements in the MRD include Flight Segment , Ground Segment, and Launch Segment, constellation, operations, and high level payload and spacecraft
- The Mission Requirements Document was generated in collaboration with ESA and is available on VSDE under LISA\Systems Engineering\Requirements
- Other trade studies and analysis currently underway:
  - Tip off and fault recovery
  - Gravitational Reference Sensor to Optical bench interface definition
  - Radiation analysis

Technology Development (1 of 5)

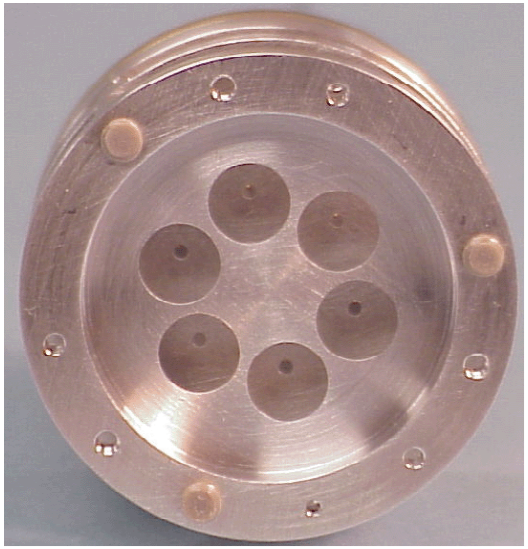
Beyond Einstein: From the Big Bang to Black Holes

- Gravitational Reference Sensor
  - Development plan in place: architect, integrator and test facility
  - Architect will be sole-sourced to ST-7 developer
  - RFI for integrator out, 3 responses received
  - RFP for test facility drafted
  - Torsion pendulum for small force studies reaches thermal noise limit



Technology Development (2 of 5)

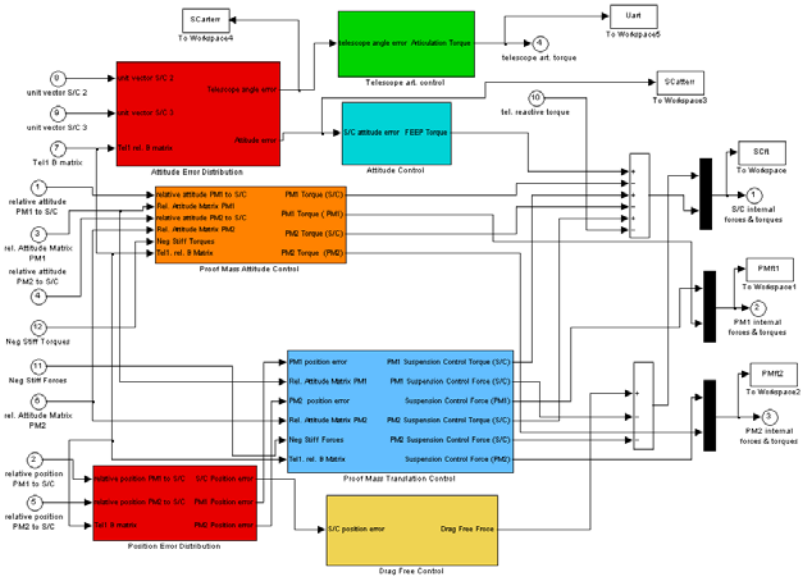
- Microthrusters
  - Decided to develop colloidal thrusters from US supplier
  - Identified lifetime as critical, long-lead time issue
  - Building up facilities and diagnostics at JPL to test colloidal thrusters

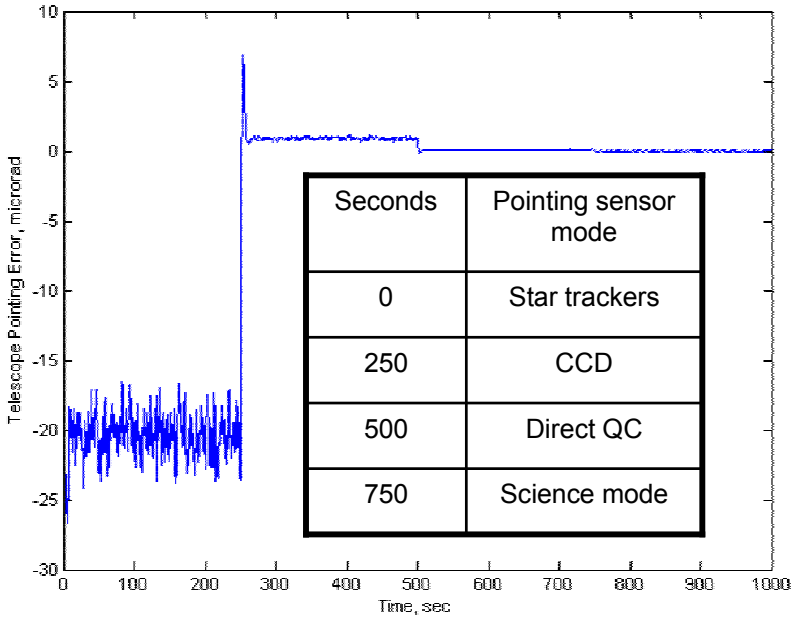


Technology Development (3 of 5)

Beyond Einstein: From the Big Bang to Black Holes

- Disturbance Reduction System Control Laws (including drag-free)
  - 19 Degree-of-Freedom Simulink model (1 spacecraft) with sensor and actuator noise complete. Controllers designed. Performance specs exceeded.
  - 57 Degree-of-Freedom model (3 spacecraft) in work.
  - Time-domain constellation acquisition model complete. Control strategy is effective and straight-forward. Pointing control meets performance requirements in about 5 minutes.



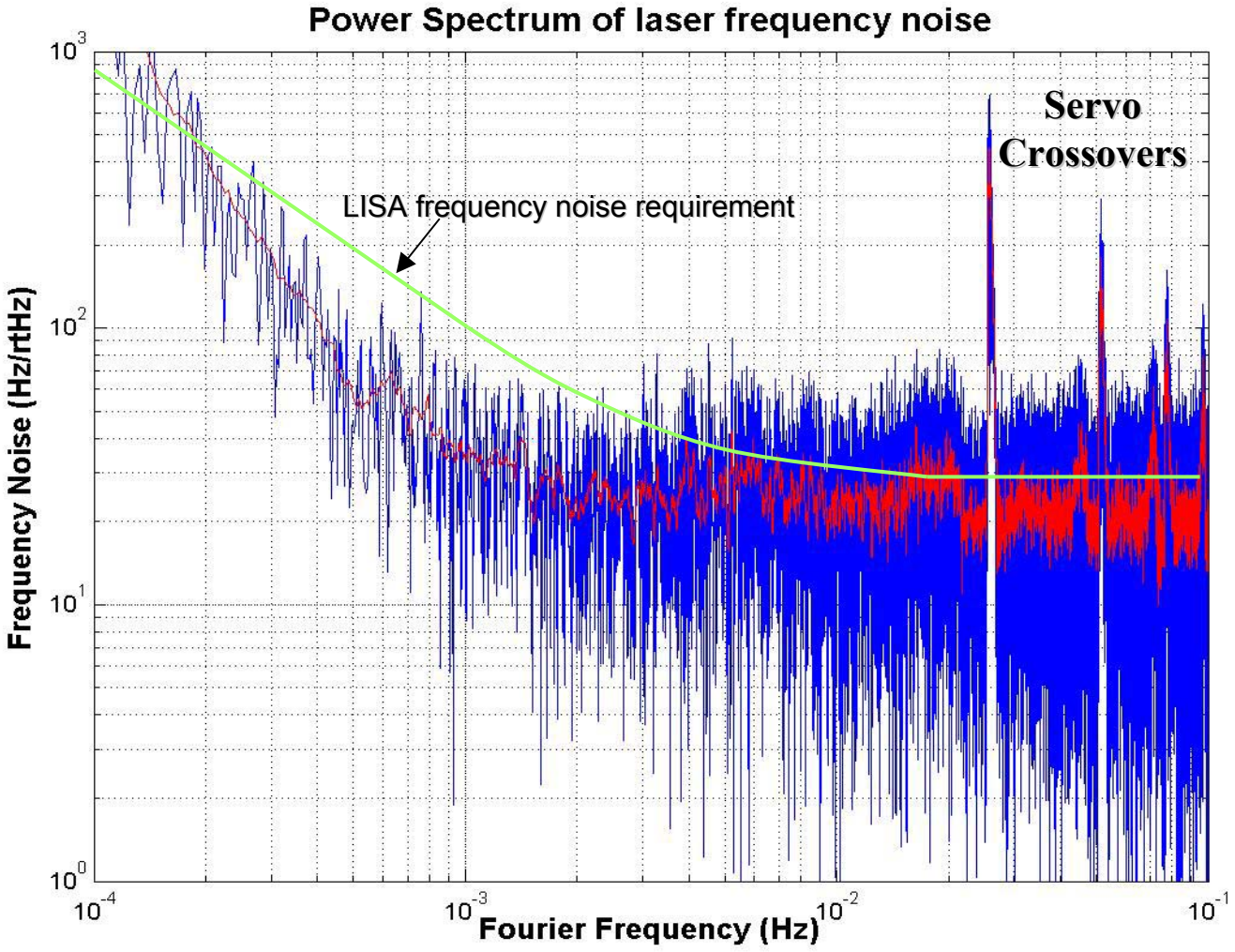


Seconds	Pointing sensor mode
0	Star trackers
250	CCD
500	Direct QC
750	Science mode

Technology Development (4 of 5)

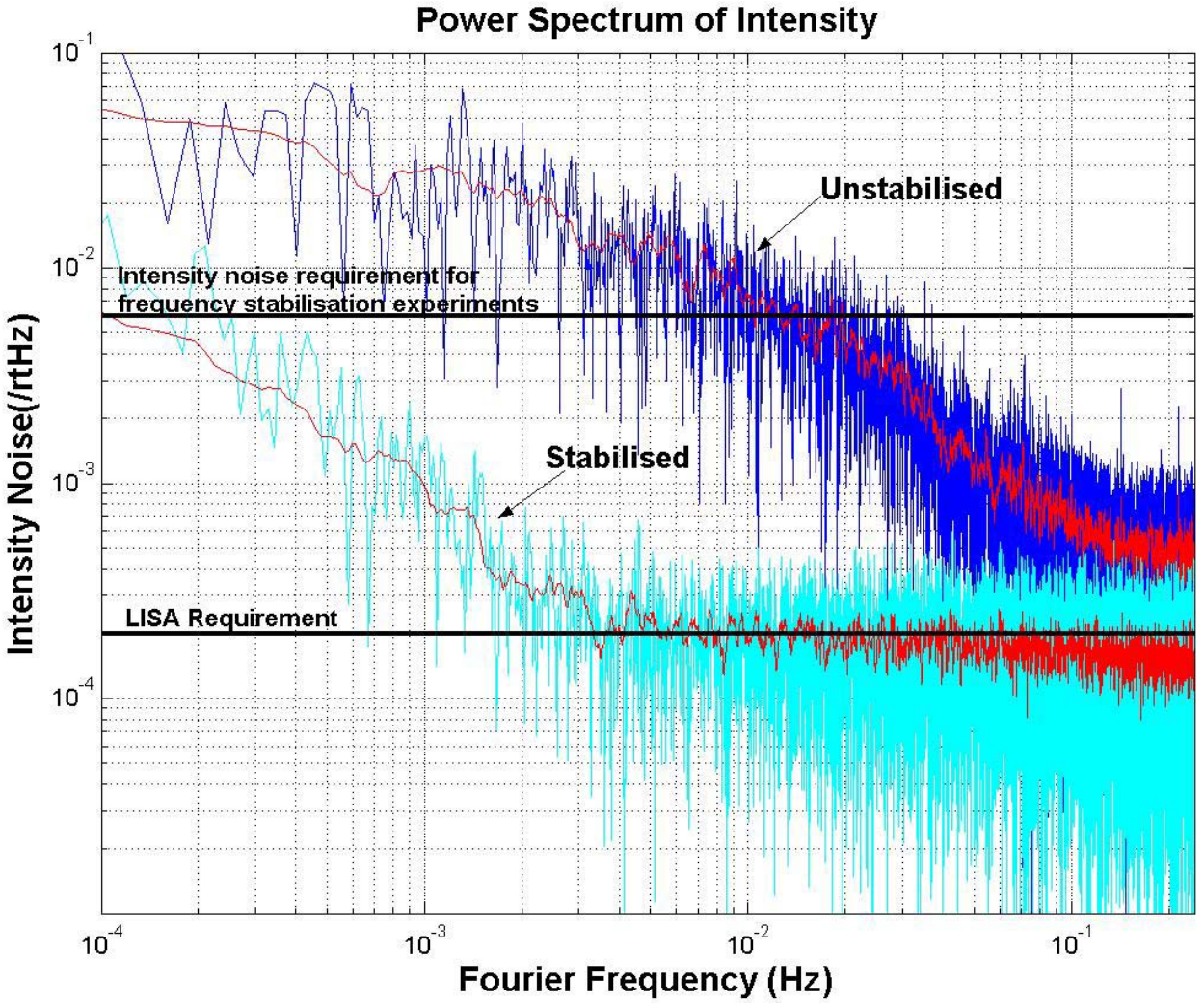
Beyond Einstein: From the Big Bang to Black Holes

- The laser frequency stability requirement has been demonstrated.



Technology Development (5 of 5)

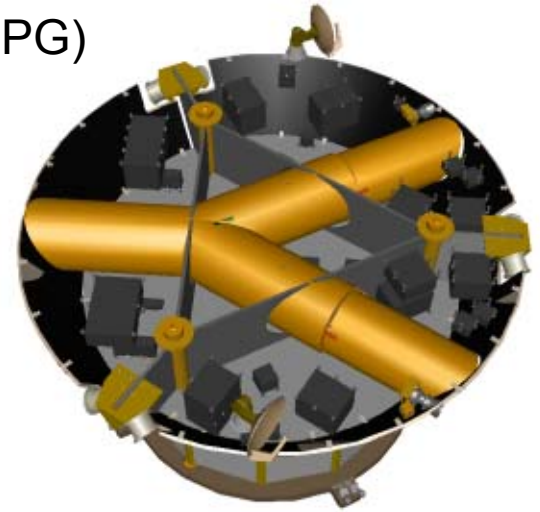
- The laser intensity stability requirement has been demonstrated

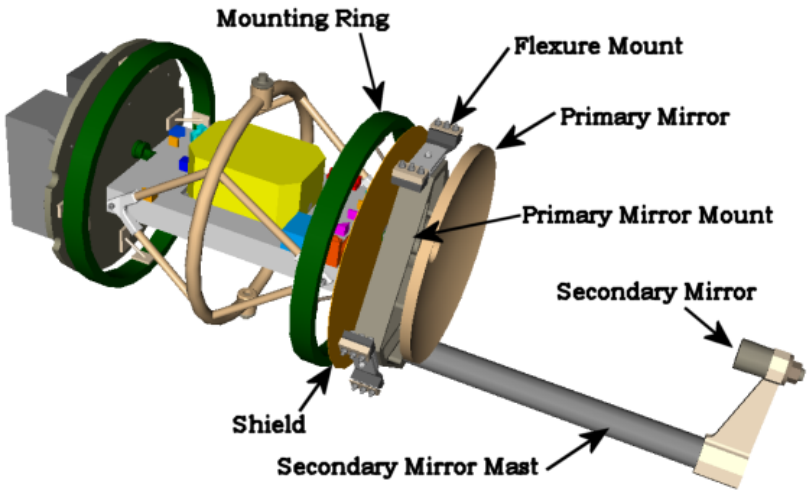


Integrated Modeling (1 of 2)

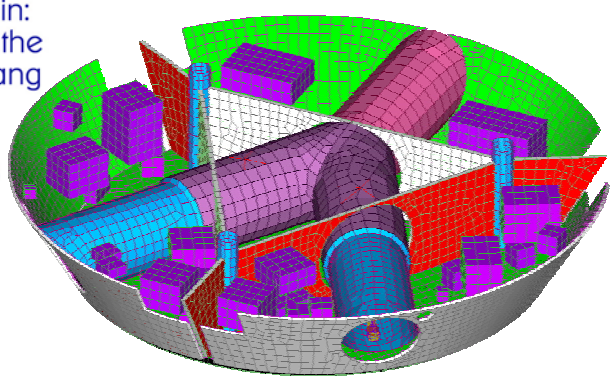
Modeling activities:

- Structural Thermal Optical Gravitational (STOPG)
- ST-7 self-gravity
- Detailed thermal analysis
- Proof mass charging
- 57 DOF controls simulation
- Acquisition simulation
- Interferometry simulation
- Scattered light
- Science data simulation
- Error budget
- Gravitational wave sensitivity
- Modeling environment

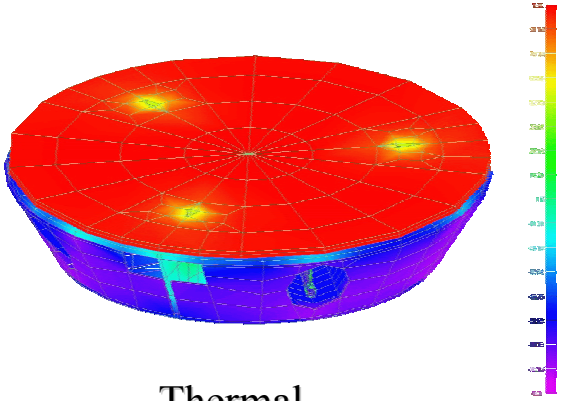




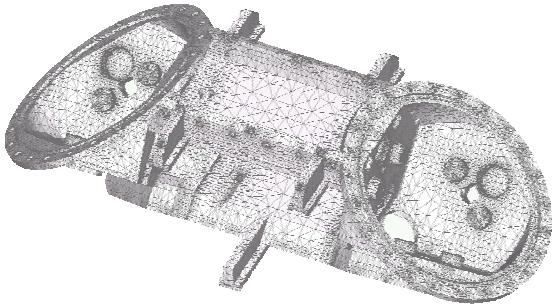
Integrated Modeling (2 of 2)



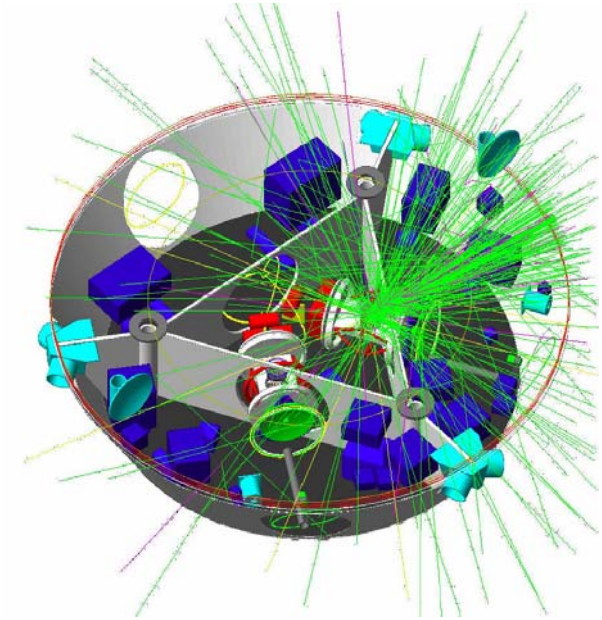
Structural



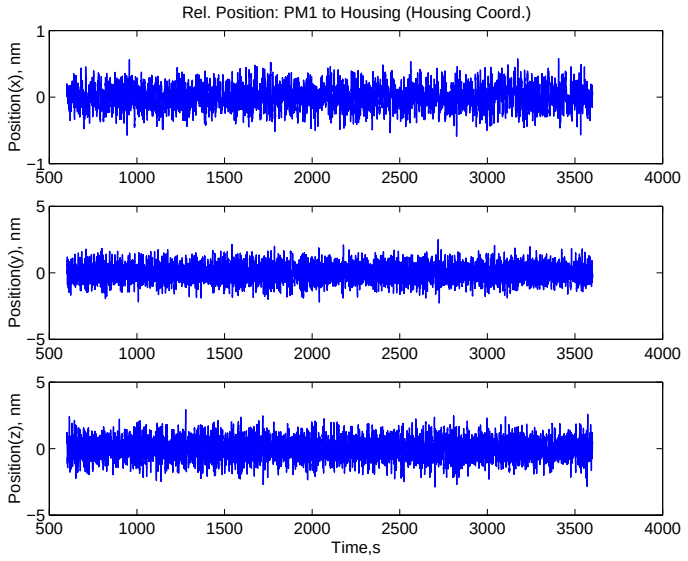
Thermal



Self-Gravity



Cosmic Ray Charging



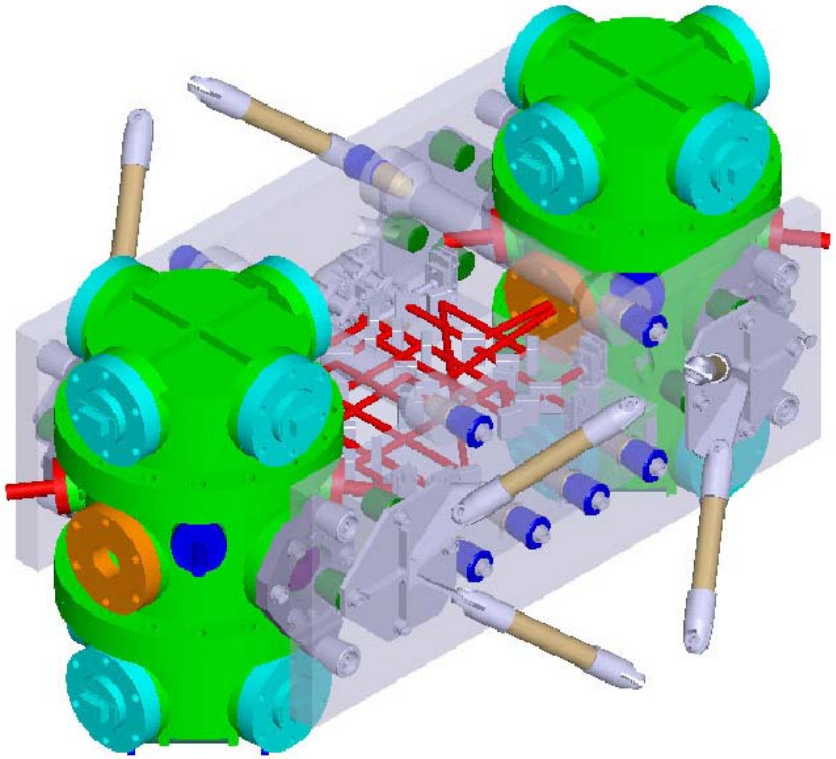
Drag-free Control

Pathfinder Status (1 of 5)

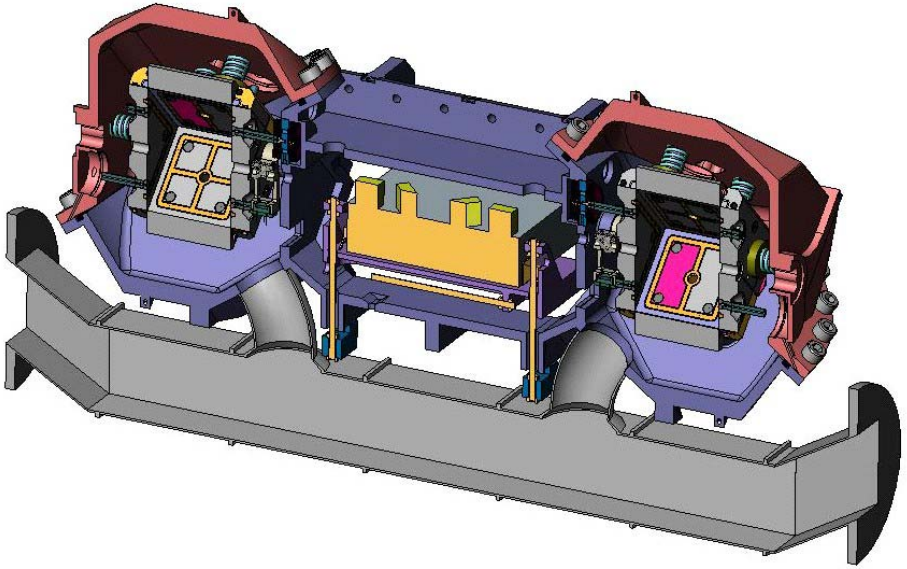
- LISA Pathfinder received the endorsement of the ESA Science Program Council for a 2004 new start in November 2003
- ESA kickoff the spacecraft implementation effort with Astrium on Feb 2, 2004
- Significant progress by the LISA Test Package (LTP) team and the ST 7 - DRS team on the gravitational sensor electrode, test mass and interferometer bench development (see the following slides)
- Life tested micro-thruster system-single needle + bellows + electronics @ 2000 hours, run to 3200 - there is no appreciable corrosion at the needle
- The ST7 begins subsystem CDR on March 5 leading to project CDR on 6/15
- The delivery date of LTP and ST 7 to the spacecraft is in the spring of 2006

Pathfinder Status (2 of 5)

Sensor Assembly

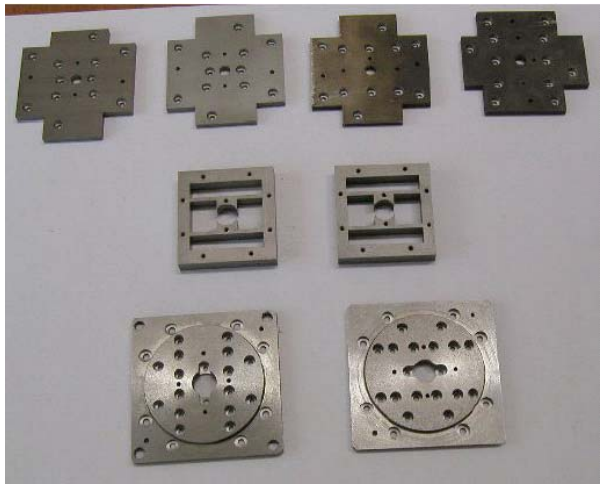


LTP



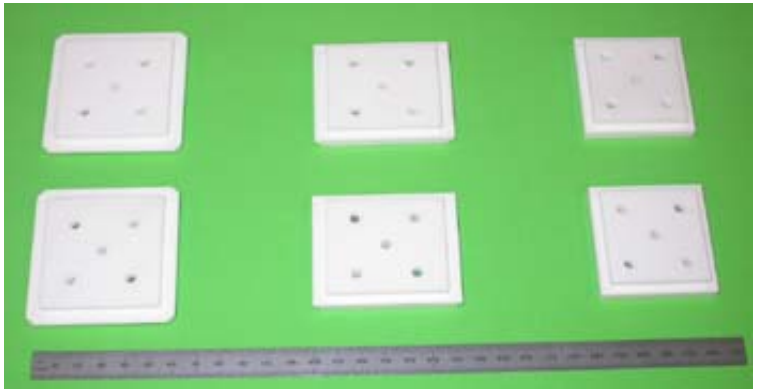
ST 7 - DRS

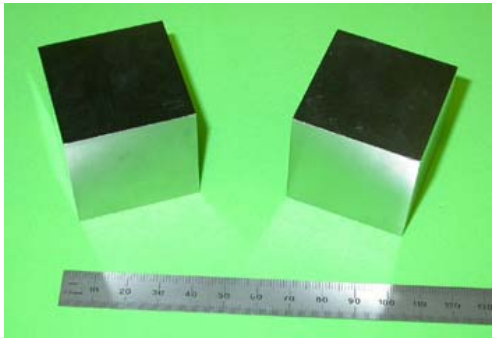
Pathfinder Status (3 of 5)



LTP Housing walls

Electrode Walls & Test Mass



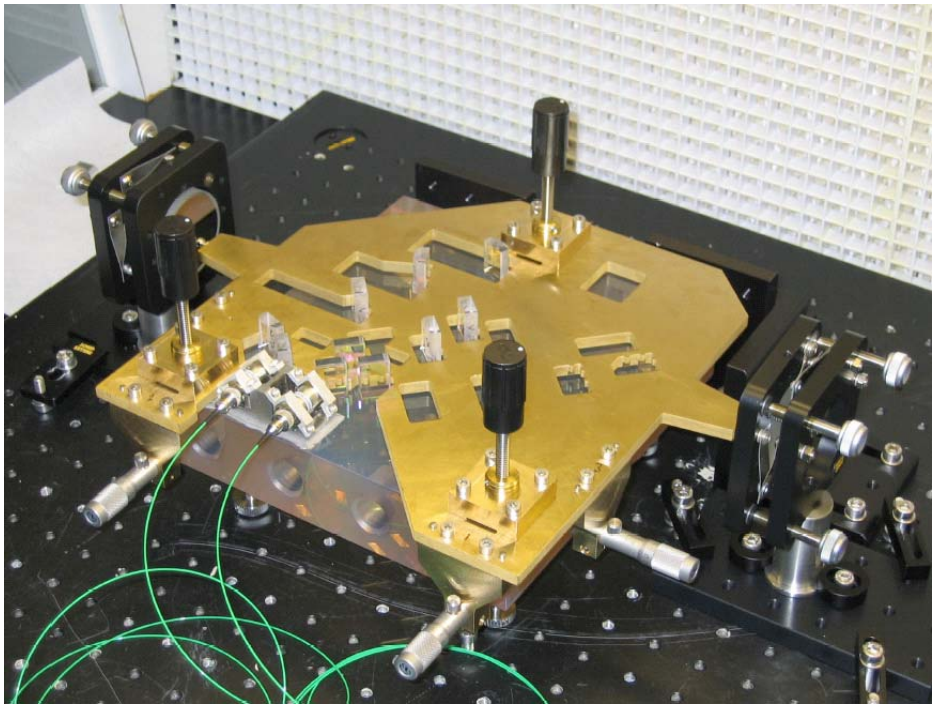


ST 7 - Ceramic Walls

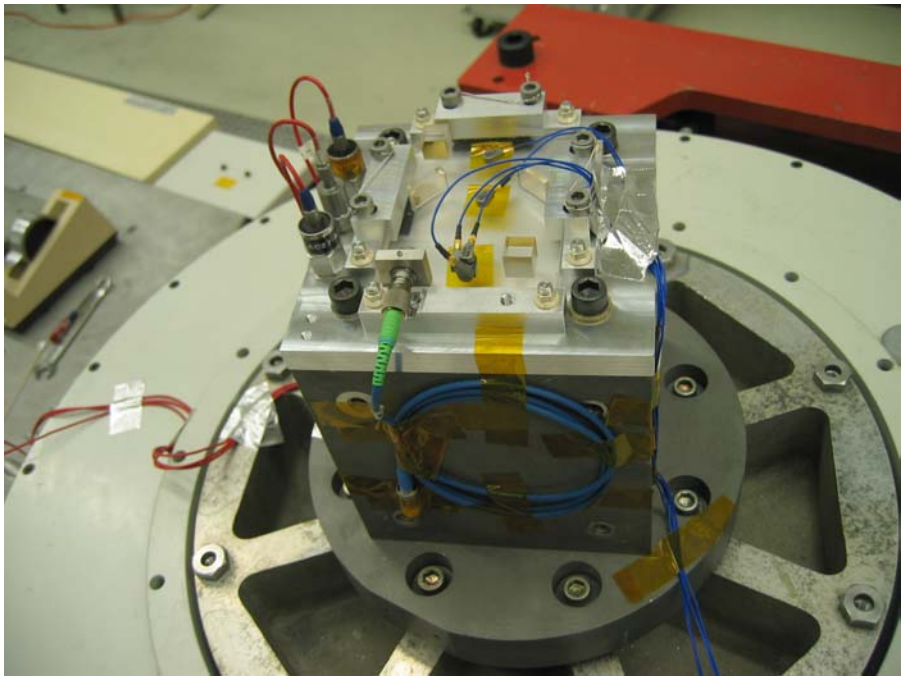
Pathfinder Status (4 of 5)

Beyond Einstein: From the Big Bang to Black Holes

Interferometer Development



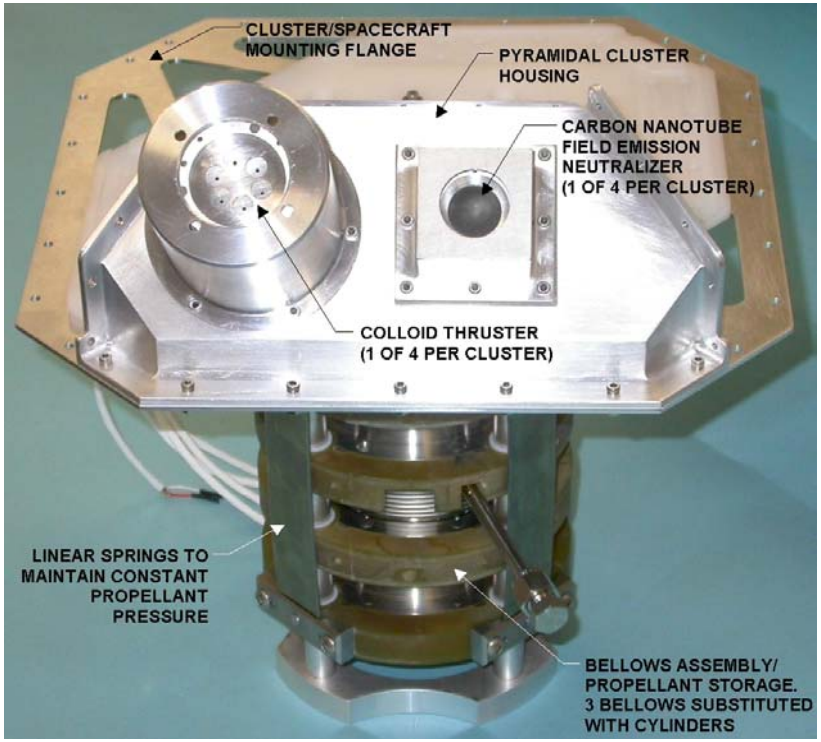
LTP
Interferometer Bench

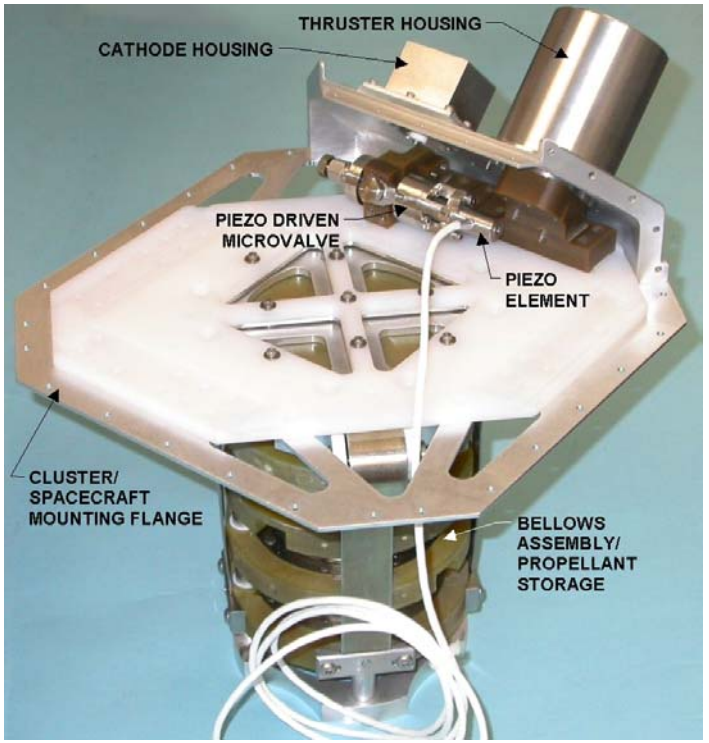


ST-7
Glass Elements Bonding Vibration Test

Pathfinder Status (5 of 5)

ST 7 Micro-Thruster Breadboard





DRS cluster breadboard that shows 1 of 4 thrusters and neutralizers

Summary

- Good progress in technology development:
  - Several important performance levels have been demonstrated in the lab
  - Lean budgets are going to result in higher risk relative to the technology
  - Initial robust posture provided areas to cut incurring minimal risk
  - Currently replanning a more risk-driven technology development approach
- Pathfinder is building hardware
- LISA Mission Requirements Document released
- More streamlined management approach in the offing
- Despite tight budgets, LISA is moving forward!